
cepton_sdk Documentation

Cepton Technologies

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OVERVIEW

The Cepton SDK provides the following features:

- **Networking:** Listen for sensor packets.
- **Capture Replay:** Read sensor packets from a PCAP file.
- **Parsing:** Parse sensor packets.
- **Calibration:** Apply sensor calibration.
- **Frame Accumulation:** Accumulate sensor points and detect frames.

Note: Currently, the Cepton LiDAR packet formats are under active development, and are not publicly available. The SDK is required for **Parsing** and **Calibration**. All other SDK features are optional, and can be done manually by the user.

1.1 Getting Started

Below is a very simple SDK usage example. For more complete examples, see [Samples](#).

```
1  #include <cepton_sdk_api.hpp>
2
3  int main(int argc, char **argv) {
4      // Initialize SDK with default options
5      CEPTON_CHECK_ERROR(
6          cepton_sdk::api::initialize(cepton_sdk::create_options(), "", true));
7
8      // Get all sensors
9      for (int i = 0; i < cepton_sdk::get_n_sensors(); ++i) {
10         cepton_sdk::SensorInformation sensor_info;
11         CEPTON_CHECK_ERROR(
12             cepton_sdk::get_sensor_information_by_index(i, sensor_info));
13     }
14
15     // Listen for points
16     cepton_sdk::api::SensorImageFrameCallback callback;
17     CEPTON_CHECK_ERROR(callback.initialize());
18     CEPTON_CHECK_ERROR(
19         callback.listen([&](cepton_sdk::SensorHandle handle, std::size_t n_points,
20                             const cepton_sdk::SensorImagePoint *c_image_points) {
21             // Get sensor info
22             cepton_sdk::SensorInformation sensor_info;
```

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```
23     CEPTON_CHECK_ERROR(  
24         cepton_sdk::get_sensor_information(handle, sensor_info));  
25  
26     // Convert points  
27     std::vector<cepton_sdk::util::SensorPoint> points(n_points);  
28     for (int i = 0; i < n_points; ++i) {  
29         cepton_sdk::util::convert_sensor_image_point_to_point(  
30             c_image_points[i], points[i]);  
31     }  
32     }));  
33  
34     // Sleep or do other work...  
35  
36     // Deinitialize SDK  
37     cepton_sdk::deinitialize().ignore();  
38 }
```

For prototyping, it is recommended to use the high level C++ API. The C++ API also acts as reference code for C API usage. Any C++ functions that directly wrap C functions are not documented; refer to the C function documentation.

The general C SDK workflow is as follows:

1. Initialize SDK (*cepton_sdk_initialize()*). See *Setup*.
2. Register point listener callback function (*cepton_sdk_listen_image_frames()*). See *Points*.
3. Wait for sensor calibration/information packets, then query sensors. See *Sensors*.
4. Sleep or run replay. Callbacks will occur asynchronously.
5. Deinitialize SDK.

1.2 Packets

The SDK passively listens for sensor UDP packets. There are 2 types of sensor packets:

- **Calibration/Information:** Contains sensor calibration, statistics, and other information. Published at ~1Hz.
- **Points:** Contains ~100 measurements. Published at ~1000Hz.

1.3 Errors

Many SDK functions return *CeptonSensorErrorCode*. If this is not *CEPTON_SUCCESS*, then the user must call *cepton_sdk_get_error()*, otherwise the SDK will complain that the error was not checked.

All sensor errors will be returned via *FpCeptonSensorErrorCallback*, which is registered in *cepton_sdk_initialize()*.

1.4 Timestamps

All `int64` timestamps are microseconds since the Unix epoch (UTC). All `float` times (measurement period, replay time, frame length, etc.) are time differences measured in seconds. Point timestamps are based on one of the following sources (the first valid source is used):

1. GPS (NMEA + PPS)
2. PTP
3. Host PC

1.5 Sensor Fusion

See *Process Single*, *Process Multi*.

1.6 Multiple Returns

To enable multiple returns, pass the `CEPTON_SDK_CONTROL_ENABLE_MULTIPLE_RETURNS` flag during initialization.

The returns are as follows:

1. Strongest signal.
2. Furthest signal, if it is not the strongest. Otherwise, the second strongest signal.

2.1 CMake

The simplest way to include the SDK is as a CMake subdirectory:

```
add_subdirectory(<cepton_sdk_source_dir>)  
...  
target_link_libraries(<target> cepton_sdk::cepton_sdk)
```

See *CMake*.

2.2 Manually

It is also possible to manually link to the SDK as follows:

1. Add the `cepton_sdk_redist/include` path.
2. Link to the correct library binary in `cepton_sdk_redist/lib` or `cepton_sdk_redist/bin`.
3. If statically linking, define `CEPTON_SDK_STATIC`.

2.3 Windows

Note: It is not possible to statically link in debug mode, since the library does not ship with debug symbols.

SAMPLES

3.1 Building

3.1.1 Unix

```
cd cepton_sdk_redist/samples
mkdir build
cd build
cmake ..
make
```

3.1.2 Windows

The following commands are for a UNIX command line (e.g. Git Bash).

```
cd cepton_sdk_redist/samples
mkdir build
cd build
cmake -G "Visual Studio 16 2019" ..
```

To build from the command line, run

```
cmake --build . --config Release
```

To build in Visual Studio

- Click File -> Open -> Project/Solution. Select cepton_sdk_redist/samples/build/cepton_sdk_samples.sln.
- Build the project.

3.2 Basic

Start with *Basic* or *C Basic*.

3.2.1 CMake

Listing 1: samples/CMakeLists.txt

```

1  #[[
2  CMake file for building samples.
3  ]]
4  cmake_minimum_required(VERSION 3.1)
5
6  set(CEPTON_SDK_SAMPLES_SOURCE_DIR "${CMAKE_CURRENT_LIST_DIR}")
7  get_filename_component(CEPTON_SDK_SOURCE_DIR
8                        "${CEPTON_SDK_SAMPLES_SOURCE_DIR}/../" ABSOLUTE)
9  list(APPEND CMAKE_MODULE_PATH "${CEPTON_SDK_SOURCE_DIR}/cmake")
10
11 include("CeptonVersion")
12 project(
13     cepton_sdk_samples
14     VERSION ${CEPTON_VERSION}
15     LANGUAGES C CXX)
16
17 include("CeptonCommon")
18
19 if(GCC OR CLANG)
20     add_flags(-Wall)
21     add_linker_flags(-pthread)
22 endif()
23
24 # cepton_sdk
25 add_subdirectory("${CEPTON_SDK_SOURCE_DIR}"
26                 "${PROJECT_BINARY_DIR}/third_party/cepton_sdk")
27
28 set(CEPTON_SDK_SAMPLE_SOURCES
29     "${CEPTON_SDK_SAMPLES_SOURCE_DIR}/advanced/frame_accumulator.cpp"
30     "${CEPTON_SDK_SAMPLES_SOURCE_DIR}/advanced/frame_detector.cpp"
31     "${CEPTON_SDK_SAMPLES_SOURCE_DIR}/advanced/process_multi.cpp"
32     "${CEPTON_SDK_SAMPLES_SOURCE_DIR}/advanced/process_single.cpp"
33     "${CEPTON_SDK_SAMPLES_SOURCE_DIR}/basic.cpp"
34     "${CEPTON_SDK_SAMPLES_SOURCE_DIR}/callback.cpp"
35     "${CEPTON_SDK_SAMPLES_SOURCE_DIR}/error.cpp")
36 foreach(path ${CEPTON_SDK_SAMPLE_SOURCES})
37     get_filename_component(name "${path}" NAME_WE)
38     add_executable(cepton_sdk_sample_${name} "${path}")
39     target_include_directories(cepton_sdk_sample_${name}
40                               PRIVATE "${CEPTON_SDK_SAMPLES_SOURCE_DIR}")
41     target_link_libraries(cepton_sdk_sample_${name} cepton_sdk::cepton_sdk)
42 endforeach()

```

3.2.2 Basic

Listing 2: samples/basic.cpp

```

1  /**
2   * Sample code for general SDK usage.
3   */
4  #include <cepton_sdk_api.hpp>
5
6  #include "common.hpp"

```

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```

7
8 /// Sample points callback.
9 class FramesListener {
10 public:
11     void on_image_frame(cepton_sdk::SensorHandle handle, std::size_t n_points,
12                       const cepton_sdk::SensorImagePoint *c_image_points) {
13         /// Get sensor info
14         cepton_sdk::SensorInformation sensor_info;
15         CEPTON_CHECK_ERROR(cepton_sdk::get_sensor_information(handle, sensor_info));
16
17         /// Convert points
18         static thread_local std::vector<cepton_sdk::util::SensorPoint> points;
19         points.resize(n_points);
20         for (int i = 0; i < (int)n_points; ++i) {
21             cepton_sdk::util::convert_sensor_image_point_to_point(c_image_points[i],
22                                                                    points[i]);
23         }
24
25         /// Print
26         std::printf("Received %i points from sensor %i\n", (int)n_points,
27                    (int)sensor_info.serial_number);
28     }
29 };
30
31 int main(int argc, char **argv) {
32     /// Parse arguments
33     check_help(argc, argv, "cepton_sdk_sample_basic [capture_path]");
34     std::string capture_path;
35     if (argc >= 2) capture_path = argv[1];
36
37     std::printf("Press Ctrl+C to stop\n");
38
39     /// Initialize SDK
40     auto options = cepton_sdk::create_options();
41
42     /// By default, return points every packet.
43
44     /// Uncomment to return points every frame.
45     options.frame.mode = CEPTON_SDK_FRAME_COVER;
46
47     /// Uncomment to return points at fixed time interval.
48     /// options.frame.mode = CEPTON_SDK_FRAME_TIMED;
49     /// options.frame.length = 0.1f;
50
51     /// Wait short duration for sensors to connect.
52     const bool enable_wait = true;
53
54     std::printf("Initializing...\n");
55     CEPTON_CHECK_ERROR(
56         cepton_sdk::api::initialize(options, capture_path, enable_wait));
57
58     /// Get all sensors
59     const int n_sensors = (int)cepton_sdk::get_n_sensors();
60     for (int i = 0; i < n_sensors; ++i) {
61         cepton_sdk::SensorInformation sensor_info;
62         CEPTON_CHECK_ERROR(
63             cepton_sdk::get_sensor_information_by_index(i, sensor_info));

```

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```

64     std::printf("Sensor: %i\n", (int)sensor_info.serial_number);
65 }
66
67 // Listen for points
68 std::printf("Listening for points...\n");
69 cepton_sdk::api::SensorImageFrameCallback callback;
70 CEPTON_CHECK_ERROR(callback.initialize());
71 FramesListener frames_listener;
72 CEPTON_CHECK_ERROR(
73     callback.listen(&frames_listener, &FramesListener::on_image_frame));
74
75 // Run (sleep or run replay)
76 CEPTON_CHECK_ERROR(cepton_sdk::api::wait(1.0));
77
78 // Deinitialize
79 cepton_sdk::deinitialize().ignore();
80 }

```

3.2.3 C Basic

Listing 3: samples/c_basic.c

```

1  /**
2   * Sample code for general C SDK usage.
3   */
4  #include <stdio.h>
5  #include <time.h>
6
7  #include <cepton_sdk.h>
8
9  void check_sdk_error() {
10     const char *error_msg;
11     const auto error_code = cepton_sdk_get_error(&error_msg);
12     printf("%s: %s\n", cepton_get_error_code_name(error_code), error_msg);
13     exit(1);
14 }
15
16 int n_frames = 0;
17
18 void image_frame_callback(CeptonSensorHandle handle, size_t n_points,
19     const struct CeptonSensorImagePoint *c_points,
20     void *user_data) {
21     ++n_frames;
22
23     // Get sensor info
24     struct CeptonSensorInformation sensor_info;
25     cepton_sdk_get_sensor_information(handle, &sensor_info);
26     check_sdk_error();
27 }
28
29 int main() {
30     // Initialize
31     struct CeptonSDKOptions options = cepton_sdk_create_options();
32     options.frame.mode = CEPTON_SDK_FRAME_COVER;
33     cepton_sdk_initialize(CEPTON_SDK_VERSION, &options, NULL, NULL);

```

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```

34  check_sdk_error();
35
36  // Wait for sensor
37  const int n_sensors = (int)cepton_sdk_get_n_sensors();
38  while (!cepton_sdk_get_n_sensors())
39      ;
40  for (int i = 0; i < n_sensors; ++i) {
41      struct CeptonSensorInformation sensor_info;
42      cepton_sdk_get_sensor_information_by_index(0, &sensor_info);
43      check_sdk_error();
44      printf("Sensor: %i\n", (int)sensor_info.serial_number);
45  }
46
47  // Listen for frames
48  cepton_sdk_listen_image_frames(image_frame_callback, NULL);
49  check_sdk_error();
50
51  // Sleep
52  while (n_frames < 10)
53      ;
54
55  // Deinitialize
56  cepton_sdk_deinitialize();
57  check_sdk_error();
58  }

```

3.2.4 Callback

Listing 4: samples/callback.cpp

```

1  /**
2   * Sample code for callback usage.
3   */
4  #include <cepton_sdk_api.hpp>
5
6  // Sample global callback.
7  void on_image_frame(cepton_sdk::SensorHandle handle, std::size_t n_points,
8                     const cepton_sdk::SensorImagePoint *c_image_points) {
9      // Handle frame...
10 }
11
12 // Sample member callback.
13 class FramesListener {
14 public:
15     void on_image_frame(cepton_sdk::SensorHandle handle, std::size_t n_points,
16                        const cepton_sdk::SensorImagePoint *c_image_points) {
17         // Handle frame...
18     }
19 };
20
21 int main(int argc, char **argv) {
22     // Initialize
23     CEPTON_CHECK_ERROR(cepton_sdk::api::initialize());
24     cepton_sdk::api::SensorImageFrameCallback callback;
25     CEPTON_CHECK_ERROR(callback.initialize());

```

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```

26
27 // Listen lambda
28 CEPTON_CHECK_ERROR(
29     callback.listen([](cepton_sdk::SensorHandle handle, std::size_t n_points,
30                       const cepton_sdk::SensorImagePoint *c_image_points) {
31         // Handle frame...
32     }));
33
34 // Listen global function
35 CEPTON_CHECK_ERROR(callback.listen(on_image_frame));
36
37 // Listen member function
38 FramesListener frames_listener;
39 CEPTON_CHECK_ERROR(
40     callback.listen(&frames_listener, &FramesListener::on_image_frame));
41
42 // Deinitialize
43 cepton_sdk::deinitialize().ignore();
44 }

```

3.2.5 Error

Listing 5: samples/error.cpp

```

1 /**
2  * Sample code for error callback usage.
3  */
4 #include <cepton_sdk_api.hpp>
5
6 int main(int argc, char** argv) {
7     // Initialize
8     cepton_sdk::api::SensorErrorCallback error_callback;
9     CEPTON_CHECK_ERROR(
10         error_callback.listen([&](cepton_sdk::SensorHandle handle,
11                                   const cepton_sdk::SensorError& error) {
12             // Handle error...
13         }));
14     CEPTON_CHECK_ERROR(cepton_sdk::initialize(
15         CEPTON_SDK_VERSION, cepton_sdk::create_options(),
16         error_callback.global_on_callback, &error_callback));
17
18     // Deinitialize
19     cepton_sdk::deinitialize().ignore();
20 }

```

3.3 Advanced

3.3.1 Frame Detector

Listing 6: samples/advanced/frame_detector.cpp

```

1  /**
2   * Sample code for custom frame detection.
3   */
4  #include <cepton_sdk_api.hpp>
5
6  int main(int argc, char **argv) {
7      std::string capture_path;
8      if (argc >= 2) capture_path = argv[1];
9
10     // Initialize
11     auto options = cepton_sdk::create_options();
12     CEPTON_CHECK_ERROR(cepton_sdk::api::initialize(options, capture_path));
13     cepton_sdk::api::SensorImageFrameCallback callback;
14     CEPTON_CHECK_ERROR(callback.initialize());
15
16     // Get sensor
17     while (cepton_sdk::get_n_sensors() == 0)
18         CEPTON_CHECK_ERROR(cepton_sdk::api::wait(0.1f));
19     cepton_sdk::SensorInformation sensor_info;
20     CEPTON_CHECK_ERROR(
21         cepton_sdk::get_sensor_information_by_index(0, sensor_info));
22
23     // Create detector
24     cepton_sdk::util::FrameDetector<> detector(sensor_info);
25     auto frame_options = cepton_sdk::create_frame_options();
26     frame_options.mode = CEPTON_SDK_FRAME_COVER;
27     CEPTON_CHECK_ERROR(detector.set_options(frame_options));
28     const int stride = sensor_info.segment_count * sensor_info.return_count;
29     CEPTON_CHECK_ERROR(callback.listen(
30         [&](cepton_sdk::SensorHandle handle, std::size_t n_points,
31             const cepton_sdk::SensorImagePoint *const c_image_points) {
32             if (handle != sensor_info.handle) return;
33
34             for (int i = 0; i < (int)n_points; i += stride) {
35                 auto &image_point = c_image_points[i];
36                 if (detector.update(image_point)) {
37                     auto &result = detector.previous_result();
38                     // `detector.period()` Frame period [seconds].
39                     // `result.timestamp` Frame timestamp [microseconds].
40
41                     // Handle frame...
42                 }
43             }
44         }));
45
46     // Run
47     CEPTON_CHECK_ERROR(cepton_sdk::api::wait(1.0f));
48
49     // Deinitialize
50     cepton_sdk::deinitialize().ignore();
51 }

```

3.3.2 Frame Accumulator

Listing 7: samples/advanced/frame_accumulator.cpp

```

1  /**
2   * Sample code for custom frame accumulation.
3   */
4  #include <cepton_sdk_api.hpp>
5
6  int main(int argc, char **argv) {
7      std::string capture_path;
8      if (argc >= 2) capture_path = argv[1];
9
10     auto frame_options = cepton_sdk::create_frame_options();
11
12     // Uncomment to return points every frame.
13     frame_options.mode = CEPTON_SDK_FRAME_COVER;
14
15     // Uncomment to return points at fixed time interval.
16     // frame_options.mode = CEPTON_SDK_FRAME_TIMED;
17     // frame_options.length = 0.1f;
18
19     // Initialize
20     auto options = cepton_sdk::create_options();
21     CEPTON_CHECK_ERROR(cepton_sdk::api::initialize(options, capture_path));
22     cepton_sdk::api::SensorImageFrameCallback callback;
23     CEPTON_CHECK_ERROR(callback.initialize());
24
25     // Get sensor
26     while (cepton_sdk::get_n_sensors() == 0)
27         CEPTON_CHECK_ERROR(cepton_sdk::api::wait(0.1f));
28     cepton_sdk::SensorInformation sensor_info;
29     CEPTON_CHECK_ERROR(
30         cepton_sdk::get_sensor_information_by_index(0, sensor_info));
31
32     // Create accumulator
33     cepton_sdk::util::FrameAccumulator accumulator(sensor_info);
34     CEPTON_CHECK_ERROR(accumulator.set_options(frame_options));
35     CEPTON_CHECK_ERROR(callback.listen(
36         [&](cepton_sdk::SensorHandle handle, std::size_t n_points,
37             const cepton_sdk::SensorImagePoint *const c_image_points) {
38             if (handle != sensor_info.handle) return;
39             accumulator.add_points(n_points, c_image_points);
40         }));
41
42     // Listen
43     CEPTON_CHECK_ERROR(accumulator.callback.listen(
44         [&](std::size_t n_points,
45             const cepton_sdk::SensorImagePoint *const c_image_points) {
46             // Handle frame...
47         }));
48
49     // Run
50     CEPTON_CHECK_ERROR(cepton_sdk::api::wait(1.0f));
51
52     // Deinitialize
53     cepton_sdk::deinitialize().ignore();
54 }

```

3.3.3 Network

Listing 8: samples/advanced/network.cpp

```

1  /**
2   * Sample code for custom networking.
3   */
4  #include <asio.hpp>
5
6  #include <cepton_sdk_api.hpp>
7
8  using asio::ip::udp;
9
10 class SocketListener {
11 public:
12     SocketListener() : m_socket(m_io_service, udp::v4()) {
13         m_socket.set_option(asio::socket_base::reuse_address(true));
14         m_socket.bind(udp::endpoint(udp::v4(), 8808));
15     }
16
17     void run() {
18         listen();
19         m_io_service.run_for(std::chrono::seconds(5));
20     }
21
22     void listen() {
23         m_socket.async_receive_from(
24             asio::buffer(m_buffer), m_end_point,
25             [this](const asio::error_code& error, std::size_t buffer_size) {
26                 if (buffer_size == 0) return;
27                 if (error == asio::error::operation_aborted) return;
28                 const CeptonSensorHandle handle =
29                     m_end_point.address().to_v4().to_ulong();
30                 // For more accurate timestamps, a separate network receive thread
31                 // should be
32                 // used.
33                 const int64_t timestamp = cepton_sdk::util::get_timestamp_usec();
34                 CEPTON_CHECK_ERROR(cepton_sdk::mock_network_receive(
35                     handle, timestamp, m_buffer.data(), buffer_size));
36                 listen();
37             });
38     }
39
40 private:
41     asio::io_context m_io_service;
42     udp::socket m_socket;
43     udp::endpoint m_end_point;
44     std::array<uint8_t, 4096> m_buffer;
45 };
46
47 int main() {
48     // Initialize
49     auto options = cepton_sdk::create_options();
50     options.control_flags |= CEPTON_SDK_CONTROL_DISABLE_NETWORK;
51     options.frame.mode = CEPTON_SDK_FRAME_COVER;
52     CEPTON_CHECK_ERROR(cepton_sdk::api::initialize(options));
53

```

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```

54 // Listen for points
55 cepton_sdk::api::SensorImageFrameCallback callback;
56 CEPTON_CHECK_ERROR(callback.initialize());
57 CEPTON_CHECK_ERROR(
58     callback.listen([](cepton_sdk::SensorHandle handle, std::size_t n_points,
59                       const cepton_sdk::SensorImagePoint* c_image_points) {
60         std::printf("Received %i points from sensor %lli\n", (int)n_points,
61                     (long long)handle);
62     }));
63
64 SocketListener listener;
65 listener.run();
66
67 // Deinitialize
68 cepton_sdk::deinitialize().ignore();
69 }

```

3.3.4 Organize Points

Listing 9: samples/advanced/organize_points.cpp

```

1  /*****
2  **
3  ** Copyright (C) 2019 Cepton Technologies. All Rights Reserved. **
4  ** Contact: https://www.cepton.com **
5  **
6  ** Sample code which opens a cepton sensor pcap file, organizes **
7  ** the points and continuously saves the most recent organized **
8  ** points to a frame to a cvs file "organized_cloud.cvs" **
9  *****/
10
11 #include <cepton_sdk_util.hpp>
12 #include <cepton_sdk/capture.hpp>
13 #include <cepton_sdk_api.hpp>
14
15 using namespace cepton_sdk::util;
16
17 int main(int argc, char** argv) {
18     if (argc < 2) return -1;
19     const std::string capture_path = argv[1];
20
21     // Initialize sdk
22     auto options = cepton_sdk::create_options();
23     options.control_flags |= CEPTON_SDK_CONTROL_DISABLE_NETWORK;
24     options.frame.mode = CEPTON_SDK_FRAME_COVER;
25     CEPTON_CHECK_ERROR(cepton_sdk::api::initialize(options));
26
27     cepton_sdk::SensorInformation sensor_info;
28
29     OrganizedCloud organized_cloud;
30     std::ofstream os;
31
32     cepton_sdk::Capture m_capture;
33     CEPTON_CHECK_ERROR(m_capture.open_for_read(capture_path));
34 }

```

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```

35 CEPTON_CHECK_ERROR(
36     cepton_sdk_set_control_flags(CEPTON_SDK_CONTROL_DISABLE_NETWORK,
37     CEPTON_SDK_CONTROL_DISABLE_NETWORK));
38 CEPTON_CHECK_ERROR(cepton_sdk_clear());
39
40 // Listen for points
41 cepton_sdk::api::SensorImageFrameCallback callback;
42 CEPTON_CHECK_ERROR(callback.initialize());
43 callback.listen([&](cepton_sdk::SensorHandle handle, std::size_t n_points,
44     const cepton_sdk::SensorImagePoint* c_image_points) {
45
46     cepton_sdk::get_sensor_information(handle, sensor_info);
47
48     std::printf("Received %i points from sensor %lli\n", static_cast<int>(n_points),
49     static_cast<long long>(handle));
50
51     Organizer organizer(sensor_info);
52
53     organizer.organize_points(n_points,
54     sensor_info.return_count,
55     c_image_points,
56     organized_cloud);
57
58     os.open("organize_cloud.csv");
59     for (const auto& point : organized_cloud.points)
60     {
61         if (point.valid)
62         {
63             float x = 0;
64             float y = 0;
65             float z = 0;
66             cepton_sdk::util::convert_image_point_to_point(
67                 point.image_x, point.image_z, point.distance, x,
68                 y, z);
69
70             os << x << "," << y << "," << z << "\n";
71         }
72     }
73     os.close();
74 });
75
76 while (true) {
77     cepton_sdk::Capture::PacketHeader header;
78     const uint8_t* data;
79     CEPTON_CHECK_ERROR(m_capture.next_packet(header, data));
80
81     const cepton_sdk::SensorHandle handle =
82         static_cast<cepton_sdk::SensorHandle>(header.ip_v4) |
83         CEPTON_SENSOR_HANDLE_FLAG MOCK;
84     CEPTON_CHECK_ERROR(cepton_sdk_mock_network_receive(
85         handle, header.timestamp, data, static_cast<size_t>(header.data_size)));
86 }
87 }

```

3.3.5 Process Multi

Listing 10: samples/advanced/process_multi.cpp

```

1  /**
2   * Sample code for processing offline data from multiple sensors.
3   */
4  #include <cepton_sdk_api.hpp>
5
6  #include "common.hpp"
7
8  struct Frame {
9      int64_t timestamp;
10     std::map<cepton_sdk::SensorHandle, std::vector<cepton_sdk::SensorImagePoint>>
11         image_points_dict;
12 };
13
14 class FrameAccumulator {
15 public:
16     void on_image_frame(
17         cepton_sdk::SensorHandle handle, std::size_t n_points,
18         const cepton_sdk::SensorImagePoint* const c_image_points) {
19         cepton_sdk::util::LockGuard lock(m_mutex);
20
21         // Add points to buffer
22         auto& image_points = m_image_points_dict[handle];
23         image_points.insert(image_points.end(), c_image_points,
24                             c_image_points + n_points);
25
26         check_and_publish();
27     }
28
29 private:
30     void check_and_publish() {
31         // Check if frame done
32         const auto timestamp = cepton_sdk::api::get_time();
33         if ((timestamp - m_timestamp) < int64_t(m_frame_length * 1e6f)) return;
34         m_timestamp = timestamp;
35
36         // Add frame to queue
37         auto frame = std::make_shared<Frame>();
38         frame->timestamp = timestamp;
39         frame->image_points_dict = m_image_points_dict;
40         m_image_points_dict.clear();
41         queue.push(frame);
42     }
43
44 public:
45     cepton_sdk::util::SingleConsumerQueue<Frame> queue;
46
47 private:
48     std::timed_mutex m_mutex;
49     float m_frame_length = 0.1f;
50     int64_t m_timestamp = 0;
51     std::map<cepton_sdk::SensorHandle, std::vector<cepton_sdk::SensorImagePoint>>
52         m_image_points_dict;
53 };
54
55 int main(int argc, char** argv) {

```

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```

56 check_help(argc, argv, "cepton_sdk_sample_process_multi capture_path");
57 if (!CEPTON_ASSERT(argc >= 2, "Capture path not provided!")) std::exit(1);
58 const std::string capture_path = argv[1];
59
60 // Initialize
61 auto options = cepton_sdk::create_options();
62 CEPTON_CHECK_ERROR(cepton_sdk::api::initialize(options, capture_path));
63 cepton_sdk::api::SensorImageFrameCallback callback;
64 CEPTON_CHECK_ERROR(callback.initialize());
65
66 // Listen
67 FrameAccumulator accumulator;
68 CEPTON_CHECK_ERROR(
69     callback.listen(&accumulator, &FrameAccumulator::on_image_frame));
70
71 while (!cepton_sdk::capture_replay::is_end()) {
72     // Get frame
73     if (accumulator.queue.empty())
74         CEPTON_CHECK_ERROR(cepton_sdk::capture_replay::resume_blocking(0.1f));
75     const auto frame = accumulator.queue.pop();
76     if (!frame) continue;
77
78     // Do processing...
79 }
80
81 // Deinitialize
82 cepton_sdk::deinitialize().ignore();
83 }

```

3.3.6 Process Single

Listing 11: samples/advanced/process_single.cpp

```

1  /**
2   * Sample code for processing offline data from single sensor.
3   */
4  #include <cepton_sdk_api.hpp>
5
6  #include "common.hpp"
7
8  struct Frame {
9      int64_t timestamp;
10     cepton_sdk::SensorHandle handle;
11     std::vector<cepton_sdk::SensorImagePoint> image_points;
12 };
13
14 int main(int argc, char **argv) {
15     check_help(argc, argv, "cepton_sdk_sample_process_single capture_path");
16     if (!CEPTON_ASSERT(argc >= 2, "Capture path not provided!")) std::exit(1);
17     const std::string capture_path = argv[1];
18
19     // Initialize
20     auto options = cepton_sdk::create_options();
21     options.frame.mode = CEPTON_SDK_FRAME_COVER;
22     CEPTON_CHECK_ERROR(cepton_sdk::api::initialize(options, capture_path));

```

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```

23 cepton_sdk::api::SensorImageFrameCallback callback;
24 CEPTON_CHECK_ERROR(callback.initialize());
25
26 // Listen
27 cepton_sdk::util::SingleConsumerQueue<Frame> queue;
28 CEPTON_CHECK_ERROR(
29     callback.listen([&](cepton_sdk::SensorHandle handle, std::size_t n_points,
30         const cepton_sdk::SensorImagePoint *c_image_points) {
31         // Add frame to queue
32         auto frame = std::make_shared<Frame>();
33         frame->timestamp = cepton_sdk::api::get_time();
34         frame->handle = handle;
35         frame->image_points.insert(frame->image_points.end(), c_image_points,
36             c_image_points + n_points);
37         queue.push(frame);
38     }));
39
40 while (!cepton_sdk::capture_replay::is_end()) {
41     // Get frame
42     if (queue.empty())
43         CEPTON_CHECK_ERROR(cepton_sdk::capture_replay::resume_blocking(0.1f));
44     const auto frame = queue.pop();
45     if (!frame) continue;
46
47     // Do processing...
48 }
49
50 // Deinitialize
51 cepton_sdk::deinitialize().ignore();
52 }

```

3.3.7 Replay

Listing 12: samples/advanced/replay.cpp

```

1  /**
2   * Sample code for custom packet replaying.
3   */
4  #include <cepton_sdk/capture.hpp>
5  #include <cepton_sdk/api.hpp>
6
7  class CaptureReplay {
8  public:
9      CaptureReplay(const std::string& path) {
10         CEPTON_CHECK_ERROR(m_capture.open_for_read(path));
11
12         CEPTON_CHECK_ERROR(
13             cepton_sdk_set_control_flags(CEPTON_SDK_CONTROL_DISABLE_NETWORK,
14                 CEPTON_SDK_CONTROL_DISABLE_NETWORK));
15         CEPTON_CHECK_ERROR(cepton_sdk_clear());
16     }
17
18     ~CaptureReplay() {
19         m_capture.close();
20         if (cepton_sdk_is_initialized()) {

```

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```

21     CEPTON_CHECK_ERROR(cepton_sdk_clear());
22 }
23 }
24
25 void run() {
26     while (true) {
27         cepton_sdk::Capture::PacketHeader header;
28         const uint8_t* data;
29         CEPTON_CHECK_ERROR(m_capture.next_packet(header, data));
30
31         const cepton_sdk::SensorHandle handle =
32             (cepton_sdk::SensorHandle)header.ip_v4 |
33             CEPTON_SENSOR_HANDLE_FLAG MOCK;
34         CEPTON_CHECK_ERROR(cepton_sdk_mock_network_receive(
35             handle, header.timestamp, data, header.data_size));
36     }
37 }
38
39 private:
40     cepton_sdk::Capture m_capture;
41 };
42
43 int main(int argc, char** argv) {
44     if (argc < 2) return -1;
45     const std::string capture_path = argv[1];
46
47     // Initialize
48     auto options = cepton_sdk::create_options();
49     options.control_flags |= CEPTON_SDK_CONTROL_DISABLE_NETWORK;
50     options.frame.mode = CEPTON_SDK_FRAME_COVER;
51     CEPTON_CHECK_ERROR(cepton_sdk::api::initialize(options));
52
53     // Listen for points
54     cepton_sdk::api::SensorImageFrameCallback callback;
55     CEPTON_CHECK_ERROR(callback.initialize());
56     CEPTON_CHECK_ERROR(
57         callback.listen([](cepton_sdk::SensorHandle handle, std::size_t n_points,
58             const cepton_sdk::SensorImagePoint* c_image_points) {
59             std::printf("Received %i points from sensor %lli\n", (int)n_points,
60                 (long long)handle);
61         }));
62
63     // Run
64     CaptureReplay replay(capture_path);
65     replay.run();
66
67     // Deinitialize
68     cepton_sdk::deinitialize().ignore();
69 }

```


INTERNAL

This page provides a brief description of what goes on inside the SDK.

4.1 Packet Received

Occurs when `cepton_sdk_mock_network_receive` is called.

1. **If the packet is a sensor information packet:**

- Update the internal stored sensor state. This information can be queried with `cepton_sdk_get_sensor_information()`.

2. **If the packet is a data packet:**

- If no corresponding sensor information packet has been received, ignore the data packet.
- Compute points from packet.
- Apply sensor calibration.
- Add points to frame accumulator. If frame is complete, emit image frame callback.

4.2 Threads

4.2.1 Networking Thread 0

Created if `CEPTON_SDK_CONTROL_DISABLE_NETWORK` is not set.

- Start listening on the UDP port (default: 8808).
- Push received packets on a queue for Thread 1.

4.2.2 Networking Thread 1

Created if `CEPTON_SDK_CONTROL_DISABLE_NETWORK` is not set.

- Pop packets from queue.
- Call internal version of `cepton_sdk_mock_network_receive`. See `Packet Received`.

4.2.3 Capture Replay Thread 0

Created by `cepton_sdk_capture_replay_resume()`.

- **While running**
 - Read next packet from PCAP file.
 - Sleep to simulate realtime delays.
 - Call `cepton_sdk_mock_network_receive`.

4.3 Concurrency

All SDK getter functions are thread safe, and can be called from callbacks. Other SDK functions are not guaranteed to be thread safe, and can cause deadlock if called from callbacks.

4.4 Minimal SDK

If desired, the following SDK features can be disabled in the SDK and performed manually by the user:

- Capture Replay: *Replay*.
- Frame Accumulation: *Frame Detector*.
- Networking: *Network*.

CHAPTER FIVE

LEGAL

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6.1 Cepton Viewer

The Cepton Viewer tool allows viewing raw Cepton sensor data. It is primarily used for sensor debugging.

- View live or replay sensor data.
- View sensor information.
- Update extrinsic sensor transforms.

6.1.1 Downloads

- [Windows](#)
- [OSX](#)
- [Linux](#)

On Linux, you will need to set a static IP for the Ethernet interface: `192.168.0.1/16` ([tutorial](#)).

6.1.2 Tutorials

- [Overview](#)
- [Network Capture](#)
- [Sensor Settings](#)

6.1.3 Main Menu

- Hover over menu items to view tooltips.
- When editing value fields, press `ESC` to undo new value and `ENTER` to accept new value.

6.1.4 Camera Controls

Command	Mouse
Rotate View	LButton
Translate View	RButton
Zoom View	MButton

6.1.5 Workflows

Open Capture

- Drag and drop capture file/folder onto the main window.

OR

- Switch to General tab.
- Select Capture -> Load Capture.

Save Capture

- Switch to General tab.
- Select Capture -> Start Capture.
- Wait for desired duration.
- Select Capture -> Stop Capture.

The capture is saved at `~/Documents/CeptonViewer/<date>/capture_<time>`.

Take Screenshot

- Switch to General tab.
- Select Tools -> Screenshot.

The screenshot is saved at `~/Documents/CeptonViewer/<date>/screenshot_<time>.png`.

Update Sensor Transforms/Clips

- Switch to Settings tab.
- For each sensor, update the transforms/clips.
- Select File -> Save/Save As....

6.1.6 Keyboard Shortcuts

GUI

Command	Key
Hide GUI	F11

Replay

Command	Key
Pause/Resume	SPACE

View

Command	Key
Reset Camera Translation	0
Camera Front View	1
Camera Top View	2
Camera Side View	3

6.2 Cepton Player

The Cepton Player tool allows creating/viewing data captures.

- View live/replay data.
- Capture data.
- Clip/filter data.
- Measure LiDAR points.
- Export LiDAR points.

6.2.1 Install

Requirements:

- Python 3

Install `cepton_alg`

```
pip3 install --user -U cepton_alg
```

To launch, run

```
cepton_player.py
```

6.2.2 Workflows

Open Capture

- Drag and drop capture file/folder onto the main window.

OR

- Select `File -> Open Replay`.

6.2.3 Camera Controls

Command	Mouse
Rotate View	LButton
Translate View	RButton
Zoom View	Scroll

6.2.4 Cursors

Interactive cursors use a combination of CTRL + LButton/RButton.

Distance Ruler

Command	Key
Enable/Disable	D
Measure	CTRL + LButton

Angle Ruler

Command	Key
Enable/Disable	A
Measure	CTRL + LButton
Set Center	CTRL + RButton

Point Selection

Command	Key
Enable/Disable	S
Select	CTRL + LButton

6.2.5 Keyboard Shortcuts

Replay

Command	Key
Pause/Resume	SPACE
Next Frame	N

View

Command	Key
Reset View Origin	0
Front View	1
Top View	2
Side View	3

6.3 Cepton Export

The Cepton Export tool allows exporting LiDAR points in various file formats.

6.3.1 Install

Requirements:

- Python 3

Install the Cepton Python SDK

```
pip3 install --user -U cepton_sdk[samples]
```

For usage, run

```
cepton_export.py -h
```


API REFERENCE

7.1 Errors

7.1.1 Types

class SensorError : public runtime_error

Error returned by most functions.

Implicitly convertible from/to `SensorErrorCode`. Getter functions do not return an error, because they cannot fail. Will call `CEPTON_ASSERT` if nonzero error is not used (call `ignore` to manually use error).

Public Functions

SensorError (`SensorErrorCode code`, **const** `std::string &msg`)

Create *SensorError* class object with `SensorErrorCode` and error message.

SensorError (`SensorErrorCode code`)

Create *SensorError* class object with error code.

SensorError ()

SensorError class default constructor.

~SensorError ()

SensorError class destructor.

SensorError (**const** *SensorError* &other)

Create *SensorError* object using *SensorError* object.

SensorError &**operator=** (**const** *SensorError* &other)

SensorError class assignment operator.

bool used () **const**

Internal use only.

const *SensorError* &**ignore** () **const**

Mark error as used.

const char ***what** () **const**

const `std::string &msg` () **const**

Returns error message.

SensorErrorCode code () const

Returns error code.

operator SensorErrorCode () const

Implicitly convert to SensorErrorCode.

operator bool () const

Returns `false` if error code is `CEPTON_SUCCESS`, `true` otherwise.

const std::string name () const

Returns error code name.

bool is_error () const

Returns true if parent object is an error.

bool is_fault () const

Returns true if parent object is a fault.

typedef int32_t CeptonSensorErrorCode

Error code returned by most library functions.

Must call `cepton_sdk_get_error` if nonzero error code is returned.

enum _CeptonSensorErrorCode

Values:

CEPTON_SUCCESS = 0

No error.

CEPTON_ERROR_GENERIC = -1

Generic error.

CEPTON_ERROR_OUT_OF_MEMORY = -2

Failed to allocate heap memory.

CEPTON_ERROR_SENSOR_NOT_FOUND = -4

Could not find sensor.

CEPTON_ERROR_SDK_VERSION_MISMATCH = -5

SDK version mismatch.

CEPTON_ERROR_COMMUNICATION = -6

Networking error.

CEPTON_ERROR_TOO_MANY_CALLBACKS = -7

Callback already set.

CEPTON_ERROR_INVALID_ARGUMENTS = -8

Invalid value or uninitialized struct.

CEPTON_ERROR_ALREADY_INITIALIZED = -9

Already initialized.

CEPTON_ERROR_NOT_INITIALIZED = -10

Not initialized.

CEPTON_ERROR_INVALID_FILE_TYPE = -11

Invalid file type.

CEPTON_ERROR_FILE_IO = -12

File IO error.

CEPTON_ERROR_CORRUPT_FILE = -13
Corrupt/invalid file.

CEPTON_ERROR_NOT_OPEN = -14
Not open.

CEPTON_ERROR_EOF = -15
End of file.

CEPTON_ERROR_NOT_SUPPORTED = -16
Functionality not supported by device.

CEPTON_ERROR_INVALID_RESPONSE = -17
Device response invalid.

CEPTON_FAULT_INTERNAL = -1000
Internal sensor parameter out of range.

CEPTON_FAULT_EXTREME_TEMPERATURE = -1001
Extreme sensor temperature fault.

CEPTON_FAULT_EXTREME_HUMIDITY = -1002
Extreme sensor humidity fault.

CEPTON_FAULT_EXTREME_ACCELERATION = -1003
Extreme sensor acceleration fault.

CEPTON_FAULT_ABNORMAL_FOV = -1004
Abnormal sensor FOV fault.

CEPTON_FAULT_ABNORMAL_FRAME_RATE = -1005
Abnormal sensor frame rate fault.

CEPTON_FAULT_MOTOR_MALFUNCTION = -1006
Sensor motor malfunction fault.

CEPTON_FAULT_LASER_MALFUNCTION = -1007
Sensor laser malfunction fault.

CEPTON_FAULT_DETECTOR_MALFUNCTION = -1008
Sensor detector malfunction fault.

7.1.2 Methods

const char *`cepton_get_error_code_name` (*CeptonSensorErrorCode error_code*)

Returns error code name string.

Returns empty string if error code is invalid.

Return Error code name string. Owned by SDK. Valid until next SDK call in current thread.

int `cepton_is_error_code` (*CeptonSensorErrorCode error_code*)

Returns whether `error_code` is of the form `CEPTON_ERROR_*`.

int `cepton_is_fault_code` (*CeptonSensorErrorCode error_code*)

Returns whether `error_code` is of the form `CEPTON_FAULT_*`.

CeptonSensorErrorCode `cepton_sdk_get_error` (**const** char ***error_msg*)

Returns and clears last sdk error.

Return Error code.

Parameters

- `error_msg`: Returned error message string. Owned by the SDK, and valid until next SDK call in the current thread.

7.2 Setup

7.2.1 Types

typedef uint32_t **CeptonSDKControl**

SDK setup flags.

enum **_CeptonSDKControl**

Values:

CEPTON_SDK_CONTROL_DISABLE_NETWORK = 1 << 1

Disable networking operations.

Useful for running multiple instances of sdk in different processes. Must pass packets manually to `cepton_sdk::mock_network_receive`.

CEPTON_SDK_CONTROL_ENABLE_MULTIPLE_RETURNS = 1 << 4

Enable multiple returns.

When set, `cepton_sdk::SensorInformation::return_count` will indicate the number of returns per laser. Can only be set at SDK initialization.

CEPTON_SDK_CONTROL_HOST_TIMESTAMPS = 1 << 6

Always use packet timestamps (disable GPS/PTP timestamps).

CEPTON_SDK_CONTROL_RESERVED = 1 << 7

typedef uint32_t **CeptonSDKFrameMode**

Controls frequency of points being reported.

enum **_CeptonSDKFrameMode**

Values:

CEPTON_SDK_FRAME_STREAMING = 0

Report points by packet.

CEPTON_SDK_FRAME_TIMED = 1

Report points at fixed time intervals.

Interval controlled by `CeptonSDKFrameOptions::length`.

CEPTON_SDK_FRAME_COVER = 2

Report points when the field of view is covered once.

Use this for a fast frame rate.

- For Sora series, detects scanline (left-to-right or right-to-left).
- For HR80 series, detects half scan cycle (left-to-right or right-to-left).
- For Vista series, detects half scan cycle.

CEPTON_SDK_FRAME_CYCLE = 3

Report points when the scan pattern goes through a full cycle.

Use this for a consistent, repeating frame. Typically 2x longer frame than `CEPTON_SDK_FRAME_COVER` mode.

CEPTON_SDK_FRAME_MODE_MAX = 3

struct CeptonSDKFrameOptions

SDK frame options.

Must use `cepton_sdk_create_frame_options` to create.

Public Members

size_t **signature**

Internal use only.

CeptonSDKFrameMode **mode**

Default: `CEPTON_SDK_FRAME_STREAMING`.

float **length**

Frame length [seconds].

Default: 0.05. Only used if `mode=CEPTON_SDK_FRAME_TIMED`.

struct *CeptonSDKFrameOptions* cepton_sdk_create_frame_options()

Create frame options.

struct CeptonSDKOptions

SDK initialization options.

Must call `cepton_sdk_create_options` to create.

Public Members

size_t **signature**

Internal use only.

CeptonSDKControl **control_flags**

Default: 0.

struct *CeptonSDKFrameOptions* frame

uint16_t **port**

Network listen port. Default: 8808.

struct *CeptonSDKOptions* cepton_sdk_create_options()

Create SDK options.

typedef void (*cepton_sdk::FpSensorErrorCallback) (SensorHandle handle, SensorErrorCode error_code, **const** char *error_msg, **const** void *error_data, size_t error_data_size, void *user_data)

7.2.2 Methods

const char *cepton_sdk_get_version_string()

Returns library version string.

This is different from `CEPTON_SDK_VERSION`.

Return Version string. Owned by SDK. Valid until next SDK call in current thread.

int **cepton_sdk_get_version_major**()

Returns library version major.

int **cepton_sdk_get_version_minor**()

Returns library version minor.

int **cepton_sdk_get_version_patch**()

Returns library version patch.

CeptonSensorErrorCode **cepton_sdk_initialize**(int ver, const struct *CeptonSDKOptions* *const options, FpCeptonSensorErrorCallback cb, void *const user_data)

Initializes settings and networking.

Must be called before any other sdk function listed below.

Parameters

- ver: CEPTON_SDK_VERSION
- options: SDK options.
- cb: Error callback.
- user_data: Error callback user instance pointer.

CeptonSensorErrorCode **cepton_sdk_deinitialize**()

Resets everything and deallocates memory.

CeptonSensorErrorCode **cepton_sdk_clear**()

Clears sensors.

Use when loading/unloading capture file.

CeptonSensorErrorCode **cepton_sdk_set_control_flags**(*CeptonSDKControl* mask, *CeptonSDKControl* flags)

Sets SDK control flags.

Parameters

- mask: Bit mask for selecting flags to change.
- flags: Bit flag values.

CeptonSDKControl **cepton_sdk_get_control_flags**()

Returns SDK control flag.

int **cepton_sdk_has_control_flag**(*CeptonSDKControl* flag)

Returns whether SDK control flag is set.

uint16_t **cepton_sdk_get_port**()

Returns network listen port.

CeptonSensorErrorCode **cepton_sdk_set_port**(uint16_t port)

Sets network listen port.

Default: 8808.

CeptonSensorErrorCode **cepton_sdk_set_frame_options**(const struct *CeptonSDKFrameOptions* *const options)

Sets frame options.

CeptonSDKFrameMode **cepton_sdk_get_frame_mode**()

Returns frame mode.

float **cepton_sdk_get_frame_length**()
Returns frame length.

7.3 Sensors

7.3.1 Types

typedef uint64_t CeptonSensorHandle
Sensor identifier.

Generated from sensor IP address.

typedef uint16_t CeptonSensorModel
Sensor model.

enum _CeptonSensorModel

Values:

HR80W = 3

HR80T_R2 = 6

VISTA_860_GEN2 = 7

VISTA_X120 = 10

SORA_P60 = 11

VISTA_P60 = 12

VISTA_X15 = 13

VISTA_P90 = 14

SORA_P90 = 15

VISTA_P61 = 16

SORA_P61 = 17

CEPTON_SENSOR_MODEL_MAX = 18

struct CeptonSensorInformation

Sensor information struct.

Returned by `cepton_sdk_get_sensor_information*`.

Public Members

CeptonSensorHandle **handle**

Sensor identifier (generated from IP address).

uint64_t **serial_number**

Sensor serial number.

char **model_name**[28]

Full sensor model name.

CeptonSensorModel **model**

Sensor model.

uint16_t **reserved**

```
char firmware_version[28]
    Firmware version string.

uint8_t major
    Major firmware version.

uint8_t minor
    Minor firmware version.

uint8_t build

uint8_t unused

struct CeptonSensorInformation::[anonymous] formal_firmware_version
    Firmware version struct.

float last_reported_temperature
    [celsius].

float last_reported_humidity
    [%].

float last_reported_age
    [hours].

float measurement_period
    Time between measurements [seconds].

int64_t ptp_ts
    PTP time [microseconds].

uint8_t gps_ts_year
    (0-99) (e.g. 2017 -> 17)

uint8_t gps_ts_month
    (1-12)

uint8_t gps_ts_day
    (1-31)

uint8_t gps_ts_hour
    (0-23)

uint8_t gps_ts_min
    (0-59)

uint8_t gps_ts_sec
    (0-59)

uint8_t return_count
    Number of returns per measurement.

uint8_t segment_count
    Number of image segments.

uint32_t flags
    Bit flags.

uint32_t CeptonSensorInformation::is_mocked : 1
    Created by capture replay.

uint32_t CeptonSensorInformation::is_pps_connected : 1
    GPS PPS is available.
```

```

uint32_t CeptonSensorInformation::is_nmea_connected : 1
    GPS NMEA is available.

uint32_t CeptonSensorInformation::is_ptp_connected : 1
    PTP is available.

uint32_t CeptonSensorInformation::is_calibrated : 1
    Calibration loaded.

uint32_t CeptonSensorInformation::is_over_heated : 1
    Hit temperature limit.

uint32_t CeptonSensorInformation::is_sync_firing_enabled : 1
    Sync fire enabled (disabled by default).

union CeptonSensorInformation::[anonymous] [anonymous]

```

7.3.2 Methods

```

int cepton_is_sora (CeptonSensorModel model)
    Returns whether sensor model is of the form SORA_*.

int cepton_is_hr80 (CeptonSensorModel model)
    Returns whether sensor model is of the form HR80_*.

int cepton_is_vista (CeptonSensorModel model)
    Returns whether sensor model is of the form VISTA_*.

size_t cepton_sdk_get_n_sensors ()
    Get number of sensors attached. Use to check for new sensors. Sensors are not deleted until deinitialization.

```

```

CeptonSensorErrorCode cepton_sdk_get_sensor_handle_by_serial_number (uint64_t serial_number,
                                                                    CeptonSensorHandle
                                                                    *const handle)

```

Looks up sensor handle by serial number.

Returns error if sensor not found.

Parameters

- serial_number: Sensor serial number.
- handle: Sensor handle.

```

CeptonSensorErrorCode cepton_sdk_get_sensor_information_by_index (size_t idx, struct
                                                                    CeptonSensorIn-
                                                                    formation *const
                                                                    info)

```

Returns sensor information by sensor index.

Useful for getting information for all sensors. Valid indices are in range [0, `cepton_sdk_get_n_sensors()`).

Returns error if index invalid.

Parameters

- idx: Sensor index. Returns error if invalid.

- `info`: Sensor information.

```
CeptonSensorErrorCode cepton_sdk_get_sensor_information (CeptonSensorHandle handle,
                                                         struct CeptonSensorInformation *const info)
```

Returns sensor information by sensor handle.

Parameters

- `handle`: Sensor handle. Returns error if invalid.
- `info`: Sensor information.

7.4 Points

7.4.1 Types

struct CeptonSensorImagePoint

Point in pinhole image coordinates (focal length = 1).

To convert to 3d point, use `cepton_sdk::util::convert_sensor_image_point_to_point`.

Public Members

`int64_t timestamp`
Unix time [microseconds].

`float image_x`
x image coordinate.

`float distance`
Distance [meters].

`float image_z`
z image coordinate.

`float intensity`
Diffuse reflectance (normal: [0-1], retroreflective: >1).

`CeptonSensorReturnType return_type`
Return type flags.

`uint8_t flags`
Bit flags.

`uint8_t CeptonSensorImagePoint::valid : 1`
If false, then distance and intensity are invalid.

`uint8_t CeptonSensorImagePoint::saturated : 1`
If true, then intensity is invalid, and the distance is inaccurate.

`union CeptonSensorImagePoint::[anonymous] [anonymous]`

`uint8_t segment_id`

`uint8_t reserved[1]`

7.4.2 Methods

```
typedef void (*FpCeptonSensorImageDataCallback)(CeptonSensorHandle handle, size_t
n_points, const struct CeptonSen-
sorImagePoint *c_points, void *user_data)
```

Callback for receiving image points.

Set the frame options to control the callback rate.

Parameters

- handle: Sensor handle.
- n_points: Points array size.
- c_points: Points array. Owned by SDK.
- user_data: User instance pointer.

```
CeptonSensorErrorCode cepton_sdk_listen_image_frames (FpCeptonSensorImageDataCallback
cb, void *const user_data)
```

Sets image frame callback.

Returns points at frequency specified by `cepton_sdk::FrameOptions::mode`. Each frame contains all possible points (use `cepton_sdk::SensorImagePoint::valid` to filter points). Points are ordered by measurement, segment, and return:

```
measurement_count = n_points / (segment_count * return_count)
idx = ((i_measurement) * segment_count + i_segment) * return_count + i_return
```

Returns error if callback already registered.

```
CeptonSensorErrorCode cepton_sdk_unlisten_image_frames ()
```

Clears image frame callback.

7.5 Capture Replay

PCAP capture file replay. Functions are not thread safe, and should only be called from the main thread.

```
int cepton_sdk_capture_replay_is_open ()
```

Returns whether capture replay is open.

```
CeptonSensorErrorCode cepton_sdk_capture_replay_open (const char *const path)
```

Opens capture replay.

Must be called before any other replay functions listed below.

Parameters

- path: Path to PCAP capture file.

```
CeptonSensorErrorCode cepton_sdk_capture_replay_close ()
```

Closes capture replay.

```
const char *cepton_sdk_capture_replay_get_filename ()
```

Returns capture replay file name.

```
int64_t cepton_sdk_capture_replay_get_start_time ()
```

Returns capture start Unix timestamp [microseconds].

float **cepton_sdk_capture_replay_get_position**()
Returns capture file position [seconds].

float **cepton_sdk_capture_replay_get_length**()
Returns capture file length [seconds].

int **cepton_sdk_capture_replay_is_end**()
Returns whether at end of capture file.

This is only relevant when using `resume_blocking` methods.

CeptonSensorErrorCode **cepton_sdk_capture_replay_seek**(float *position*)
Seek to capture file position [seconds].

Parameters

- *position*: Seek position in range [0.0, capture length).

CeptonSensorErrorCode **cepton_sdk_capture_replay_set_enable_loop**(int *enable_loop*)
Sets capture replay looping.

If enabled, replay will automatically rewind at end.

int **cepton_sdk_capture_replay_get_enable_loop**()
Returns whether capture replay looping is enabled.

CeptonSensorErrorCode **cepton_sdk_capture_replay_set_speed**(float *speed*)
Sets speed multiplier for asynchronous replay.

float **cepton_sdk_capture_replay_get_speed**()
Returns capture replay speed.

CeptonSensorErrorCode **cepton_sdk_capture_replay_resume_blocking_once**()
Replay next packet in current thread without sleeping.

Pauses replay thread if running.

CeptonSensorErrorCode **cepton_sdk_capture_replay_resume_blocking**(float *duration*)
Replay multiple packets synchronously.

No sleep between packets. Pauses replay thread if running.

Parameters

- *duration*: Duration to replay. Must be non-negative.

int **cepton_sdk_capture_replay_is_running**()
Returns true if replay thread is running.

CeptonSensorErrorCode **cepton_sdk_capture_replay_resume**()
Resumes asynchronous replay thread.

Packets are replayed in realtime. Replay thread sleeps in between packets.

CeptonSensorErrorCode **cepton_sdk_capture_replay_pause**()
Pauses asynchronous replay thread.

7.6 Networking

Network callback for debugging.

7.6.1 Types

```
typedef void (*FpCeptonNetworkReceiveCallback) (CeptonSensorHandle handle, int64_t
                                                timestamp, const uint8_t *buffer, size_t
                                                buffer_size, void *user_data)
```

Callback for receiving network packets.

Returns error if callback already set.

Parameters

- `handle`: Sensor handle.
- `timestamp`: Packet Unix timestamp [microseconds].
- `buffer`: Packet bytes.
- `buffer_size`: Buffer size.
- `user_data`: User instance pointer.

7.6.2 Methods

```
CeptonSensorErrorCode cepton_sdk_listen_network_packet (FpCeptonNetworkReceiveCallback
                                                         cb, void *const user_data)
```

Sets network packets callback.

For internal use.

Returns error if callback already registered.

Parameters

- `cb`: Callback.
- `user_data`: User instance pointer.

```
CeptonSensorErrorCode cepton_sdk_unlisten_network_packet ()
```

Clears network packet callback.

7.7 Serial

Serial callback. Primarily used for receiving data from GPS/INS attached to sensor.

7.7.1 Types

```
typedef void (*FpCeptonSerialReceiveCallback) (CeptonSensorHandle handle, const char
                                                *str, void *user_data)
```

Callback for receiving serial data (e.g. NMEA).

Parameters

- `handle`: Sensor handle.
- `str`: Serial line string. Owned by SDK.
- `user_data`: User instance pointer.

7.7.2 Methods

CeptonSensorErrorCode **cepton_sdk_listen_serial_lines** (*FpCeptonSerialReceiveCallback* *cb*,
void ***const** *user_data*)

Sets serial line callback.

Useful for listening to NMEA data from GPS attached to sensor. Each callback contains 1 line of serial data (including newline characters).

Returns error if callback already registered.

Parameters

- *cb*: Callback.
- *user_data*: User instance pointer.

CeptonSensorErrorCode **cepton_sdk_unlisten_serial_lines** ()
Clears serial line callback.

7.8 C++

High level C++ API for prototyping (`cepton_sdk.hpp`, `cepton_sdk_api.hpp`). Methods are agnostic to live/replay mode.

`bool cepton_sdk::api::is_live()`
Returns whether capture replay is not open.

`bool cepton_sdk::api::is_end()`
Returns whether capture replay is at the end and enable loop is false.

`int64_t cepton_sdk::api::get_time()`
Returns live or capture replay time.

SensorError `cepton_sdk::api::wait` (float *t_length* = -1.0f)
Sleeps or resumes capture replay for duration.
If *t_length* < 0, then waits forever.

7.8.1 Errors

CEPTON_PROCESS_ERROR (code)
Add context to error.

CEPTON_CHECK_ERROR (code)
If error, raise.

CEPTON_LOG_ERROR (code)
If error, print.

CEPTON_RETURN_ERROR (code)
If error, return.

7.8.2 Setup

SensorError cepton_sdk::api::initialize (Options *options* = create_options(), **const** std::string &capture_path = "", bool enable_wait = false)

Initialize SDK and optionally starts capture replay.

If enable_wait is true, waits a few seconds to initialize sensors.

SensorError cepton_sdk::api::open_replay (**const** std::string &capture_path, bool enable_wait = false)

Opens capture replay.

If enable_wait is true, replays a few seconds to initialize sensors.

bool cepton_sdk::api::has_control_flags (Control *mask*)

Returns whether indicated control flags are set.

SensorError cepton_sdk::api::enable_control_flags (Control *mask*, bool *tf*)

Enables/disables indicated control flags.

class SensorErrorCallback : **public** cepton_sdk::util::Callback<SensorHandle, **const** *SensorError*>

Callback for sensor errors.

Public Static Functions

static void global_on_callback (SensorHandle *handle*, SensorErrorCode *error_code*, **const** char **error_msg*, **const** void ***const** *error_data*, size_t *error_data_size*, void ***const** *instance*)

class SensorImageFrameCallback : **public** cepton_sdk::util::Callback<SensorHandle, std::size_t, **const** SensorImagePointCloud>

Callback for image frames.

Must call initialize before use.

Public Functions

~SensorImageFrameCallback ()

SensorImageFrameCallback class destructor.

SensorError initialize ()

Initializes *SensorImageFrameCallback* object.

SensorError deinitialize ()

Deinitializes *SensorImageFrameCallback* object.

bool is_initialized () **const**

Returns true if *SensorImageFrameCallback* is initialized.

7.8.3 Sensors

bool cepton_sdk::api::has_sensor_by_serial_number (uint64_t *serial_number*)

Returns whether SDK has sensor with serial number.

SensorError `cepton_sdk::api::get_sensor_information_by_serial_number` (uint64_t *serial_number*,
SensorIn-
formation
&*info*)

Returns sensor information by serial number.

Returns error if sensor not found.

`std::vector<uint64_t> cepton_sdk::api::get_sensor_serial_numbers()`

Returns serial numbers for all sensors.

7.9 Utilities

Utility functions and classes for prototyping (*cepton_sdk_util.hpp*).

7.9.1 Common

`int64_t cepton_sdk::util::get_timestamp_usec()`

Returns current unix timestamp [microseconds].

This is the timestamp format used by all sdk functions.

7.9.2 Points

struct SensorPoint

3d point class.

Can't subclass from SensorImagePoint, needs to be POD.

Public Members

`int64_t timestamp`

Unix time [microseconds].

`float image_x`

x image coordinate.

`float distance`

Distance [meters].

`float image_z`

z image coordinate.

`float intensity`

Diffuse reflectance.

`CeptonSensorReturnType return_type`

Strongest or farthest return.

`uint8_t flags`

Bit flags.

`uint8_t cepton_sdk::util::SensorPoint::valid : 1`

If false, then the distance and intensity are invalid.

```

uint8_t cepton_sdk::util::SensorPoint::saturated : 1
    If true, then the intensity is invalid. Also, the distance is valid, but inaccurate.

union cepton_sdk::util::SensorPoint::[anonymous] [anonymous]

float x
    x cartesian coordinate

float y
    y cartesian coordinate

float z
    z cartesian coordinate

void cepton_sdk::util::convert_sensor_image_point_to_point (const    SensorImage-
                                                             Point    &image_point,
                                                             SensorPoint &point)
    Convenience    method    to    convert    cepton_sdk::SensorImagePoint    to
    cepton_sdk::SensorPoint.

```

7.9.3 Callbacks

```
template<typename ...TArgs>
```

```
class Callback
```

Expands SDK callback functionality.

Allows for multiple callbacks to be registered. Allows for registering lambdas and member functions. See `samples/basic.cpp`.

Public Functions

```
void clear ()
    Clear all listeners.
```

```
SensorError listen (const std::function<void> TArgs...
                    > &func, uint64_t *const id = nullptr) Register std::function.
```

Parameters

- func: *Callback* function.
- id: Identifier used for unlisten.

```
template<typename TClass>
SensorError listen (TClass *const instance, MemberFunction<TClass, TArgs...> func, uint64_t
                  *const id = nullptr)
    Register instance member function.
```

Parameters

- instance: Parent class instance pointer.
- func: *Callback* function pointer.
- id: Identifier used for unlisten.

```
SensorError unlisten (uint64_t id)
    Unregister function.
```

Parameters

- `id`: Identifier returned by `listen`.

void **operator()** (TArgs... *args*) **const**

Emit callback.

Calls all registered functions with *args*.

Public Static Functions

static void **global_on_callback** (TArgs... *args*, void ***const** *instance*)

Used for registering as c callback.

7.9.4 Frames

template<typename **TData** = bool>

class FrameDetector : **public** cepton_sdk::util::internal::FrameDetectorBase<*TData*>

Detects frames in streaming sensor data.

Result::type

- Sora: 0=left-right, 1=right-left
- HR80: 0=left-right, 1=right-left
- Vista: undefined

Public Functions

FrameDetector (**const** SensorInformation &*sensor_info*)

FrameDetector class constructor passing in SensorInformation.

const FrameOptions &**get_options** () **const**

Returns frame options for *FrameDetector*.

SensorError **set_options** (**const** FrameOptions &*options*)

Set frame options.

void **reset** ()

Completely resets detector.

Only use if also clearing points accumulator.

bool **update** (**const** SensorImagePoint &*point*, **const** TData &*data* = TData())

Returns true if frame found.

Automatically resets after frame is found.

class FrameAccumulator

Accumulates image points, and emits frames to callback.

See `samples/frame.cpp`.

Public Functions

FrameAccumulator (**const** SensorInformation &*sensor_info*)
FrameAccumulator class constructor passing in SensorInformation.

FrameOptions **get_options** () **const**
 Return frame options for *FrameAccumulator*.

SensorError **set_options** (**const** FrameOptions &*options*)
 Set options for *FrameAccumulator*.

void **clear** ()

void **add_points** (std::size_t *n_points*, **const** SensorImagePoint ***const** *image_points*)

Public Members

Callback<std::size_t, **const** SensorImagePoint *> **callback**
 Frames callback.

7.9.5 Organizer

struct OrganizedCloud
 The *OrganizedCloud* struct An organized version of the cepton point cloud.

Public Functions

int **getIndex** (int *row*, int *col*, int *n_return*)
 getIndex Returns the index of the point corresponding to the inputted row, col and return number.

Return

Parameters

- [in] *row*: Row index
- [in] *col*: Col index
- [in] *n_return*: Return index

Public Members

int64_t **timestamp_start**
 timestamp_start The time of the oldest point in the cloud

int64_t **timestamp_end**
 timestamp_end The time of the newest point in the cloud

int **height**
 height Height of the cloud. Represents how many rows there are in the cloud

int **width**
 width Width of the cloud. Represents how many columns there are in the cloud

int **n_returns**
 n_returns Number of return represented by the cloud.

```
std::vector<CellInfo> info_cells
```

info_cells Vector of cell info which provide information about the matching points

```
std::vector<CeptonSensorImagePoint> points
```

points Vector of organized points. Stored in Return, Row, Col order. So to get a point at row 10, col 15, return 1 would be points[(row * width

- col) n_returns + return

```
struct CellInfo
```

The *CellInfo* struct.

Public Members

```
bool occupied_cell = false
```

occupied_cell Is the cell at this index occupied with a point. If false can't assume this represents free space.

```
int original_index = -1
```

original_index Index of the point that was used to generate the organized point. Can be used to match back with orginial data if required. Should only be use if occupied_cell is true.

```
class Organizer
```

The *Organizer* class Performs organization on cepton unorganized points. Creates an angular grid, places each point within that grid and outputs a point for each location in the grid in a row/col format. Thread safe. Defaults to a 0.4deg spaced grid.

Public Types

```
enum OrganizerMode
```

Values:

```
RECENT
```

Output the most recent point from the frame that fell within the grid

```
CENTER
```

Output the center of the grid. Uses median point distance.

Public Functions

```
Organizer (cepton_sdk::SensorInformation sensor_info)
```

Organizer.

Parameters

- sensor_info: Sensor info for organizer. Used to set min/max angles

```
void organize_points (const int num_points_in, const int n_returns, const CeptonSensorImagePoint *const unorganized_points, cepton_sdk::util::OrganizedCloud &organized_points)
```

organize_points

Parameters

- [in] num_points_in: Number of unorganized points

- [in] `n_returns`: Number of returns
- [in] `unorganized_points`: Unorganized points to process
- [out] `organized_points`: Points in organized form

void **mode** (*OrganizerMode* mode)
mode

Parameters

- `mode`: Change the mode of the organizer. [RECENT] Points are the most recent which fill within the grid. [CENTER] Points outputted are at the center of the grid. More even spacing but less accurate.

void **binSize** (float *bin_size*)
binSize Change the bin size of the organizer

Parameters

- `bin_size`: The horizontal and vertical bin size to set. In radians

void **settings** (*OrganizerSettings* *organizer_settings*)
settings

Parameters

- `organizer_settings`: Change organizer settings

OrganizerSettings **settings** ()
settings

Return The settings the organizer is using

struct OrganizerSettings

Public Members

float **horizontal_range_radians** = to_radians(70.f)

float **vertical_range_radians** = to_radians(30.f)

float **horizontal_bin_size_radians** = to_radians(0.4f)

float **vertical_bin_size_radians** = to_radians(0.4f)

OrganizerMode **mode** = *OrganizerMode*::RECENT

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